SECTION FIVE

COAL AND THE ENVIRONMENT

» Our consumption of energy can have a significant impact on the environment. Minimising the negative impacts of human activities on the natural environment – including energy use – is a key global priority. »

However, it is important to balance concerns for the environment alongside the priorities of economic and social development. 'Sustainable development' encapsulates all three areas and has been defined as: "…development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

While coal makes an important contribution to economic and social development worldwide, its environmental impact has been a challenge.

Coal Mining & the Environment

Coal mining – particularly surface mining – requires large areas of land to be temporarily disturbed. This raises a number of environmental challenges, including soil erosion, dust, noise and water pollution, and impacts on local biodiversity. Steps are taken in modern mining operations to minimise these impacts. Good planning and environmental management minimises the impact of mining on the environment and helps to preserve biodiversity.

Land Disturbance

In best practice, studies of the immediate environment are carried out several years before a coal mine opens in order to define the existing conditions and to identify sensitivities and potential problems. The studies look at the impact of mining on surface and ground water, soils, local land use, and native vegetation and wildlife populations (see koala case study on page 30). Computer simulations can be undertaken to model impacts on the local environment. The findings are then reviewed as part of the process leading to the award of a mining permit by the relevant government authorities.

Mine Subsidence

A problem that can be associated with underground coal mining is subsidence, whereby the ground level lowers as a result of coal having been mined beneath. Any land use activity that could place public or private property or valuable landscapes at risk is clearly a concern.

A thorough understanding of subsistence patterns in a particular region allows the effects of underground mining on the surface to be quantified. This ensures the safe, maximum recovery of a coal resource, while providing protection to other land uses.

The Moura mine was the first operation in Australia to establish a commercial coal mine methane business alongside its coal mining operations. The project has the potential to make overall GHG emissions savings equivalent to 2.8 million tonnes of CO_2 per annum. Photograph courtesy of Anglo Coal Australia.

Water Pollution

Acid mine drainage (AMD) is metal-rich water formed from the chemical reaction between water and rocks containing sulphur-bearing minerals. The runoff formed is usually acidic and frequently comes from areas where ore- or coal mining activities have exposed rocks containing pyrite, a sulphur-bearing mineral. However, metal-rich drainage can also occur in mineralised areas that have not been mined.

AMD is formed when the pyrite reacts with air and water to form sulphuric acid and dissolved iron. This acid run-off dissolves heavy metals such as copper, lead and mercury into ground and surface water.

There are mine management methods that can minimise the problem of AMD, and effective mine design can keep water away from acid-generating materials and help prevent AMD occurring. AMD can be treated actively or passively. Active treatment involves installing a water treatment plant, where the AMD is first dosed with lime to neutralise the acid and then passed through settling tanks to remove the sediment and particulate metals. Passive treatment aims to develop a self-operating system that can treat the effluent without constant human intervention.

Dust & Noise Pollution

During mining operations, the impact of air and noise pollution on workers and local communities can be minimised by modern mine planning techniques and specialised equipment. Dust at mining operations can be caused by trucks being driven on unsealed roads, coal crushing operations, drilling operations and wind blowing over areas disturbed by mining.

Dust levels can be controlled by spraying water on roads, stockpiles and conveyors. Other steps can also be taken, including fitting drills with dust collection systems and purchasing additional land surrounding the mine to act as a buffer zone between the mine and its neighbours. Trees planted in these buffer zones can also minimise the visual impact of mining operations on local communities. Noise can be controlled through the careful selection of equipment and insulation and sound enclosures around machinery. In best practice, each site has noise and vibration monitoring equipment installed, so that noise levels can be measured to ensure the mine is within specified limits.

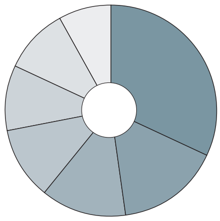
Rehabilitation

Coal mining is only a temporary use of land, so it is vital that rehabilitation of land takes place once mining operations have ceased. In best practice a detailed rehabilitation or reclamation plan is designed and approved for each coal mine, covering the period from the start of operations until well after mining has finished. Land reclamation is an integral part of modern mining operations around the world and the cost of rehabilitating the land once mining has ceased is factored into the mine's operating costs.

Mine reclamation activities are undertaken gradually – with the shaping and contouring of spoil piles, replacement of topsoil, seeding with grasses and planting of trees taking place on the mined-out areas. Care is taken to relocate streams, wildlife, and other valuable resources.

Reclaimed land can have many uses, including agriculture, forestry, wildlife habitation and recreation.

Major Sources of Methane Emissions



Livestock	32%
Oil and Natural Gas	16%
Solid Waste	13%
Rice	11%
Waste Water	10%
Other	10%
Coal	8%

Source: US EPA

Using Methane from Coal Mines

Methane (CH_4) is a gas formed as part of the process of coal formation. It is released from the coal seam and the surrounding disturbed strata during mining operations.

Methane is a potent greenhouse gas – it is estimated to account for 18% of the overall global warming effect arising from human activities (CO_2 is estimated to contribute 50%). While coal is not the only source of methane emissions – production of rice in wet paddy fields and other agricultural activities are major emitters – methane from coal seams can be utilised rather than released to the atmosphere with a significant environmental benefit.

Coal mine methane (CMM) is methane released from coal seams during coal mining. Coalbed methane (CBM) is methane trapped within coal seams that have not, or will not, be mined.

Methane is highly explosive and has to be drained during mining operations to keep working conditions safe. At active underground mines, large-scale ventilation systems move massive quantities of air through the mine, keeping the mine safe but also releasing methane into the atmosphere at very low concentrations. Some active and abandoned mines produce methane from degasification systems, also known as gas drainage systems, which use wells to recover methane.

As well as improving safety at coal mines, the use of CMM improves the environmental performance of a coal mining operation and can have a commercial benefit. Coal mine methane has a variety of uses, including on-site or off-site electricity production, use in industrial processes and fuel for cofiring boilers.

Coalbed methane can be extracted by drilling into and mechanically fracturing unworked coal seams. While the CBM is utilised, the coal itself remains unmined.

Coal Use & the Environment

Global consumption of energy raises a number of environmental concerns. For coal, the release of pollutants, such as oxides of sulphur and nitrogen (SOx and NOx), and particulate and trace elements, such as mercury, have been a challenge. Technologies have been developed and deployed to minimise these emissions.

ENVIRONMENTAL MANAGEMENT

KOALA VENTURE

Environmental management and rehabilitation at coal mines does not simply mean protecting the natural vegetation – it also includes protecting the wildlife at the mine. At the Blair Athol opencast coal mine in Queensland, Australia, this means taking care of the native koala population.

The Koala Venture project between Rio Tinto Coal Australia – operators of the mine – and the University of Queensland began when the mine management approached the university for help on how to minimise the impact of its mining operations on the colony of koalas on the land.

The project aims to manage the koala population, their safety and security on the Blair Athol mine lease and adjacent areas. The koalas feeding and roosting habits are monitored to improve rehabilitation practices, while their health and reproductive status are studied to ensure that the population of koala is maintained.

In order to advance operations at the opencast mine, vegetation that includes koala habitat must be cleared. A two-stage tree clearing procedure is used to minimise disruption to the koalas. This process involves leaving some of the trees used by koalas for several months, while removing the remainder. Research has shown that the koalas will then voluntarily tend to move into the rehabilitated areas featuring their preferred trees or into adjacent undisturbed areas.

The Koala Venture is the first ever study undertaken of the breeding ecology of free-ranging koalas using DNA testing and has made some important breakthroughs in the understanding of how koalas breed.

Information gathered at the Blair Athol mine has been incorporated into the National Strategy for the Conservation of the Koala in Australia.

More information on the Koala Venture can be found at www.koalaventure.com

A more recent challenge has been that of carbon dioxide emissions (CO_2). The release of CO_2 into the atmosphere from human activities – often referred to as anthropogenic emissions – has been linked to global warming. The combustion of fossil fuels is a major source of anthropogenic emissions worldwide. While the use of oil in the transportation sector is the major source of energy-related CO_2 emissions, coal is also a significant source. As a result, the industry has been researching and developing technological options to meet this new environmental challenge.

Technological Response

Clean coal technologies (CCTs) are a range of technological options which improve the environmental performance of coal. These technologies reduce emissions, reduce waste, and increase the amount of energy gained from each tonne of coal.

Different technologies suit different types of coal and tackle different environmental problems. The choice of technologies can also depend on a country's level of economic development. More expensive, highly advanced technologies may not be suitable in developing countries, for example, where cheaper readily-available options can have a larger and more affordable environmental benefit.

Reducing Particulate Emissions

Emissions of particulates, such as ash, have been one of the more visible side-effects of coal combustion in the past. They can impact local visibility, cause dust problems and affect people's respiratory systems. Technologies are available to reduce and, in some cases, almost eliminate particulate emissions.

Coal Cleaning

Coal cleaning, also known as coal beneficiation or coal preparation, increases the heating value and the quality of the coal by lowering levels of sulphur and mineral matter (see Section 2 for a description of coal preparation techniques). The ash content of coal can be reduced by over 50%, helping to cut waste from coal combustion. This is particularly important in countries where coal is transported long distances prior to use, since it improves the economics of transportation by removing most of the non-combustible material. Coal cleaning can also improve the efficiency of coal-fired power stations, which leads to a reduction in emissions of carbon dioxide.

Electrostatic Precipitators & Fabric Filters

Particulates from coal combustion can be controlled by electrostatic precipitators (ESP) and fabric filters. Both can remove over 99.5% of particulate emissions and are widely applied in both developed and developing countries. In electrostatic precipitators, particulate-laden flue gases pass between collecting plates, where an electrical field creates a charge on the particles. This attracts the particles towards the collecting plates, where they accumulate and can be disposed of.

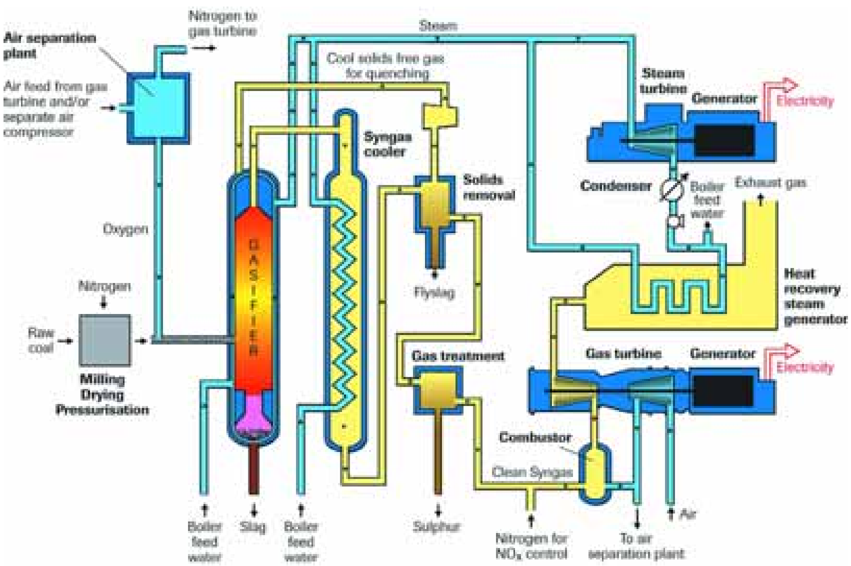
Fabric filters, also known as 'baghouses', are an alternative approach and collect particles from the flue gas on a tightly woven fabric primarily by sieving.

The use of particulate control equipment has a major impact on the environmental performance of coal-fired power stations. At the Lethabo power station in South Africa,

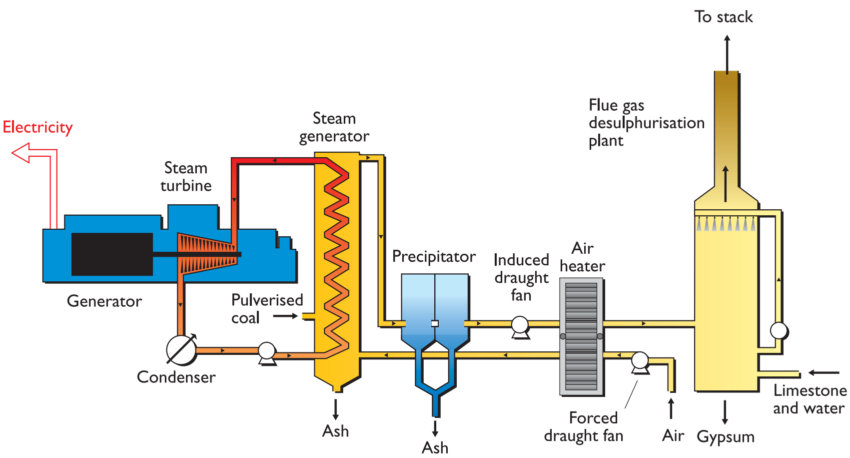
Definition

Carbon dioxide is a colourless, odourless, incombustible gas formed during decomposition, combustion and respiration.

An Integrated Gasification Combined Cycle Unit



A Flue Gas Desulphurisation System



electrostatic precipitators remove 99.8% of fly ash, some of which is sold to the cement industry. For Eskom, the plant operator, the use of ESPs has had a major impact on the environmental performance of its power stations. Between 1988 and 2003, it reduced particulate emissions by almost 85% while power generated increased by over 56%.

Preventing Acid Rain

Acid rain came to global attention during the latter part of the last century, when acidification of lakes and tree damage in parts of Europe and North America was discovered.

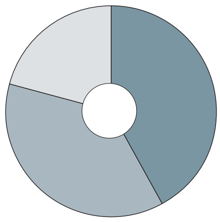
Acid rain was attributed to a number of factors, including acid drainage from deforested areas and emissions from fossil fuel combustion in transportation and power stations.

Oxides of sulphur (SOx) and nitrogen (NOx) are emitted to varying degrees during the combustion of fossil fuels. These gases react chemically with water vapour and other substances in the atmosphere to form acids, which are then deposited in rainfall.

Steps have been taken to significantly reduce SOx and NOx emissions from coal-fired power stations. Certain approaches also have the additional benefit of reducing other emissions, such as mercury.

Sulphur is present in coal as an impurity and reacts with air when coal is burned to form SOx. In contrast, NOx is formed when any fossil fuel is burned. In many circumstances, the use of low sulphur coal is the most economical way to control sulphur dioxide. An alternative approach has been the development of flue gas desulphurisation (FGD) systems for use in coal-fired power stations.

CO_2 Emissions from Fossil Fuels



Oil	41%
Coal	38%
Gas	21%

Source: IEA 2004

FGD systems are sometimes referred to as 'scrubbers' and can remove as much as 99% of SOx emissions. In the USA, for example, sulphur emissions from coal-fired power plants decreased by 61% between 1980 and 2000 – even though coal use by utilities increased by 74%.

Oxides of nitrogen can contribute to the development of smog as well as acid rain. NOx emissions from coal combustion can be reduced by the use of 'low NOx' burners, improving burner design and applying technologies that treat NOx in the exhaust gas stream. Selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR) technologies can reduce NOx emissions by around 80-90% by treating the NOx post-combustion.

Fluidised bed combustion (FBC) is a high efficiency, advanced technological approach to reducing both NOx and SOx emissions. FBC is able to achieve reductions of 90% or more. In FBC systems, coal is burned in a bed of heated particles suspended in flowing air. At high air velocities, the bed acts as a fluid resulting in the rapid mixing of the particles. This fluidising action allows complete coal combustion at relatively low temperatures.

Reducing Carbon Dioxide Emissions

A major environmental challenge facing the world today is the risk of 'global warming'.

Naturally occurring gases in the atmosphere help to regulate the earth's temperature by trapping other radiation - this is known as the greenhouse effect (see diagram on page 36). Human activities, such as the combustion of fossil fuels, produce additional greenhouse gases (GHG) which accumulate in the atmosphere. Scientists believe that the build-up of these gases is causing an enhanced greenhouse effect, which could cause global warming and climate change.

The major greenhouse gases include water vapour, carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.

Coal is one of many sources of greenhouse gas emissions generated by human activities and the industry is committed to minimising its emissions.

Greenhouse gases associated with coal include methane, carbon dioxide (CO_2) and nitrous oxide (N_2O). Methane is released from deep coal mining (see earlier section). CO_2 and N_2O are released when coal is used in electricity generation or industrial processes, such as steel production and cement manufacture.

Combustion Efficiency

An important step in reducing CO_2 emissions from coal combustion has been improvements in the thermal efficiencies of coal-fired power stations. Thermal efficiency is a measure of the overall fuel conversion efficiency for the electricity generation process. The higher the efficiency levels, the greater the energy being produced from the fuel.

The global average thermal efficiency of coal-fired power stations is around 30%, with the OECD average at around 38%. In comparison, China has an average thermal efficiency of all its installed coal-fired capacity of some 27% (though newer stations with significantly improved efficiencies are increasingly being installed).

New 'supercritical' technology allows coal-fired power plants to achieve overall thermal efficiencies of 43-45%. These higher levels are possible because supercritical plant operate at higher steam temperatures and pressures than conventional plant. Ultrasupercritical power plants can achieve efficiency levels of up to 50% by operating at even higher temperatures and pressures. More than 400 supercritical plant are operating worldwide, including a number in developing countries.

An alternative approach is to produce a gas from coal – this is achieved in integrated gasification combined cycle (IGCC) systems. In IGCC, coal is not combusted directly but reacted with oxygen and steam to produce a 'syngas' composed mainly of hydrogen and carbon monoxide. This syngas is cleaned of impurities and then burnt in a gas turbine to generate electricity and to produce steam for a steam power cycle.

IGCC systems operate at high efficiencies, typically in the mid-40s but plant designs offering close to 50% efficiencies are available. They also remove 95-99% of NOx and SOx emissions. Work is being undertaken to make further gains in efficiency levels, with the prospect of net efficiencies of 56% in the future. There are around 160 IGCC plants worldwide.

IGCC systems also offer future potential for hydrogen production linked with carbon capture and storage technologies (described in more detail in the next section).

Carbon Capture & Storage

An important factor in the future use of coal will be the level to which CO_2 emissions can be reduced. Much has been done to achieve this, such as the improvements in efficiency levels. One of the most promising options for the future is carbon capture and storage (CCS).

The Coal-fired Route to CO_2 Reductions

Up to 5% CO_2 Reductions

Coal Upgrading
Includes coal washing/drying, briquetting. Widespread use throughout the world.

Up to 22% CO_2 Reductions

Efficiency Improvements of Existing Plant
Conventional coal-fired subcritical generation has improved significantly in its efficiency (38-40%) so reducing emissions. Supercritical and ultrasupercritical plant offer even higher efficiencies (already up to 45%). Improved efficiency subcritical plant operate around the world. Supercritical and ultrasupercritical plant operate successfully in Japan, USA, Europe, Russia and China.

Up to 25% CO_2 Reductions

Advanced Technologies
Very high efficiencies and low emissions from innovative technologies such as integrated gasification combined cycle (IGCC). pressurised fluidised bed combustion (PFBC) and in the future integrated gasification fuel cells (IGFC). IGCC and PFBC operational in USA, Japan and Europe, IGFC at R&D stage.

Up to 99% CO_2 Reductions

Zero Emissions
Carbon capture and storage. Significant international R&D efforts ongoing. FutureGen project aims to have demonstration plant operational within 10 years.

TECHNOLOGICAL INNOVATION

Carbon capture and storage technologies allow emissions of carbon dioxide to be stripped out of the exhaust stream from coal combustion or gasification and disposed of in such a way that they do not enter the atmosphere. Technologies that allow CO_2 to be captured from emission streams have been used for many years to produce pure CO_2 for use in the food processing and chemicals industry. Petroleum companies often separate CO_2 from natural gas before it is transported to market by pipeline. Some have even started permanently storing CO_2 deep underground in saline aquifers.

While further development is needed to demonstrate the viability of separating out CO_2 from high volume, low CO_2 concentration flue gases from coal-fired power stations, carbon capture is a realistic option for the future.

Once the CO_2 has been captured, it is essential that it can be safely and permanently stored. There are a number of storage options at various stages of development and application.

Carbon dioxide can be injected into the earth's subsurface, a technique known as geological storage. This technology allows large quantities of CO_2 to be permanently stored and is the most comprehensively studied storage option. As long as the site is carefully chosen, the CO_2 can be stored for very long periods of time and monitored to ensure there is no leakage.

Depleted oil and gas reservoirs are an important option for geological storage. Latest estimates suggest that depleted oilfields have a total capacity of some 126 Gigatonnes (Gt) of CO_2. Depleted natural gas reservoirs have a considerably larger storage capacity of some 800 Gt of CO_2. Unmineable coal beds are estimated to have a storage capacity of some 150 Gt of CO_2.

Large amounts of CO_2 can also be stored in deep saline water-saturated reservoir rocks, allowing countries to store their CO_2 emissions for many hundreds of years. Firm estimates of the CO_2 storage capacity in deep saline formations have not yet been fully developed, though it has been estimated that it could range between 400 and 10,000 Gt. There are a number of projects demonstrating the effectiveness of CO_2 storage in saline aquifers. The Norwegian company Statoil is undertaking a project at the Sleipner field located in the Norwegian section of the North Sea. The Nagaoka project, started in Japan in 2002, is a smaller-scale, five-year project researching and demonstrating the potential of CO_2 storage in on-shore and off-shore aquifers.

Underground Storage Options for CO_2

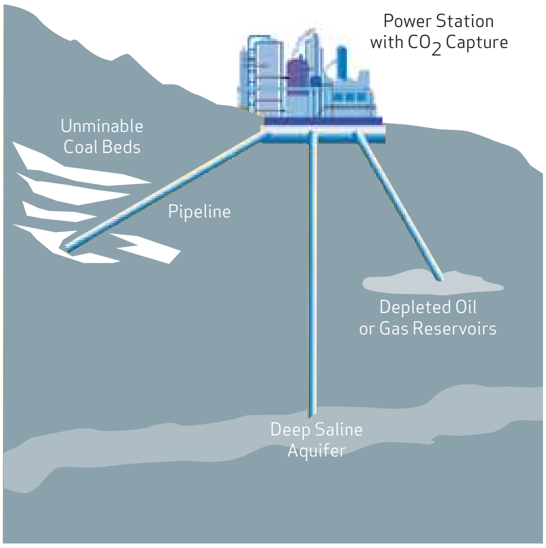


Diagram courtesy of IEA GHG R&D Programme

The Greenhouse Effect

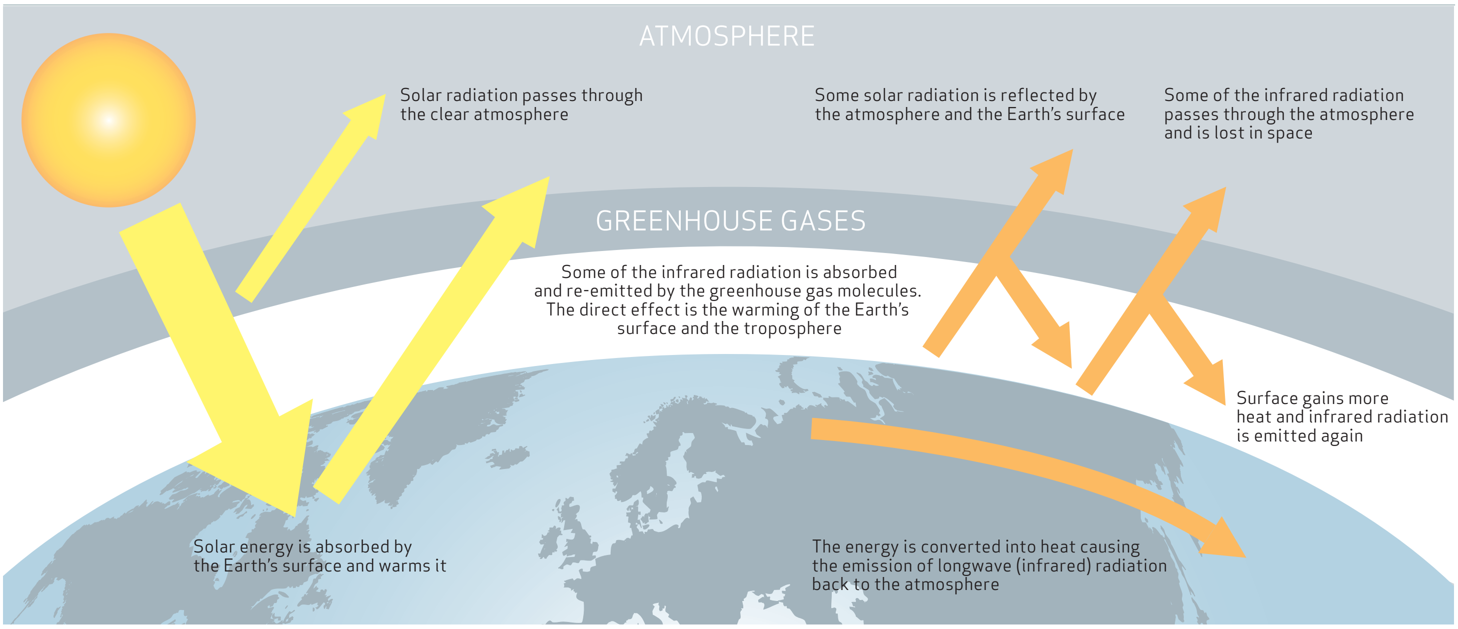


Diagram courtesy of the Intergovernmental Panel on Climate Change

The storage of CO_2 can also have an economic benefit by allowing increased production of oil and coalbed methane. These techniques are referred to as enhanced oil recovery (EOR) and enhanced coalbed methane recovery (ECBM). The CO_2 can be used to 'push' oil out of underground strata and is already widely used in the oil industry. The Weyburn Enhanced Oil Recovery project uses CO_2 from a lignite-fired power station in the USA and transports it through a 205 mile pipeline to the Weyburn oilfield in Canada to boost oil production. Around 5000 tonnes or 2.7 m^3 of CO_2 per day are injected into the oilfield, an amount which would otherwise have been released into the atmosphere.

ECBM allows CO_2 to be stored in unmineable coal seams and improves the production of coalbed methane as a valuable by-product.

Carbon capture and storage offers the potential for the large-scale CO_2 reductions needed to stabilise atmospheric concentrations of CO_2.

Coal & Renewable Energy

The continued development and deployment of renewable energy will play an important role in improving the environmental performance of future energy production. However, there are a number of significant practical and economic barriers that limit the projected rate of growth of renewable energy.

Renewable energy can be intermittent or unpredictable and 'site-dependent', which means they are only available at specific locations. Wind energy, for example, depends on whether and how strongly the wind is blowing and even the best wind farms do not normally operate for more than about one-third of the time. Many forms of biomass are seasonal and can be difficult to transport. Coal-fired electricity can help support the growth of renewable energy by balancing out their intermittencies in power supply. Coal can provide convenient, cheap base-load power while renewables can be used to meet peak demand. The economics and efficiency of biomass renewables can also be improved by co-firing with coal.

While clean coal technologies are improving the environmental performance of coal-fired power stations, its role as an affordable and readily available energy source offers wider environmental benefits by supporting the development of renewables.

Overcoming Environmental Impacts

The environmental impact of our energy consumption is a concern for us all. Limiting the negative effects of coal production and use is a priority for the coal industry and one which has been the focus of research, development and investment. Much has been achieved – technologies have been developed and are widely used to limit particulate emissions, NOx and SOx and trace elements. Improvements in the efficiency of coal combustion have already achieved significant reductions in carbon dioxide emissions. The wider use of technologies to improve the environmental performance of coal will be essential, particularly in developing countries where coal use is set to markedly increase.

Technological innovation and advancement, such as carbon capture and storage, offers many future prospects for tackling CO_2 emissions from coal use in the future.

SECTION FIVE END

The UNFCCC & GHG Emissions

The United Nations Framework Convention on Climate Change (UNFCCC) sets an overall framework for intergovernmental efforts to tackle climate change. It opened for signature at the Earth Summit in Rio de Janeiro in 1992 and entered into force in 1994. Under the Convention, governments:

- Gather and share information on GHG emissions, national policies and best practices.
- Launch national strategies for addressing GHG emissions and adapting to expected impacts, including the provision of financial and technological support to developing countries.
- Cooperate in preparing for adaptation to the impacts of climate change.

Countries that are parties to the UNFCCC meet annually at the Conference of the Parties (COP). It was at COP3, held in Kyoto in 1997, that countries negotiated the Kyoto Protocol, which set legally-binding targets for emissions reductions.

The Kyoto Protocol entered into force in February 2005. At that time there were 128 countries who were Parties to the Protocol, 30 of whom are developed countries with emissions targets. Both Australia and the USA have refused to ratify the Protocol but are undertaking their own domestic measures to stabilise GHG emissions.

Kyoto sets targets for industrialised countries "with a view to reducing their overall emissions of such gases by at least 5% below existing 1990 levels, in the commitment period 2008-2012".

Kyoto covers emissions of the six main greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride. (SF_6). Rather than placing a specific target on each of the gases, the overall emissions targets for all six is combined and translated into 'CO_2 equivalents', used to produce a single figure.

Kyoto Protocol Emissions Targets (1990* to 2008/2012)

+10%	Iceland
+8%	Australia**
+1%	Norway
+0%	New Zealand, Russian Federation, Ukraine
-5%	Croatia
-6%	Canada, Hungary, Japan, Poland
-7%	USA**
-8%	EU15, Bulgaria, Czech Republic, Estonia, Latvia, Liechtenstein, Lithuania, Monaco, Romania, Slovakia, Slovenia, Switzerland

* The base year is flexible in the case of Economies in Transition (EIT) countries
** Countries who have declared their intention not to ratify the Protocol